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Wind power resource in the south-western region of Algeria

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ABSTRACT

In this study, we present a statistical analysis of wind speeds at Tindouf in Algeria using Risoe National Laboratory's Wind Atlas Analysis and Application Program (WAsP). It requires information related to the sheltering obstacles, surface roughness changes and terrain height variations in order to calculate their effects on the wind. Wind data, consisting of hourly wind speed records over a 5-year period, 2002–2006, were obtained from SONELGAZ R&D Office; the average wind speed at a height of 17 m above ground level was found to range from 7.19 to 7.95 m/s. The Weibull distributions parameters (c and k) were found to vary between 8.0 and 8.9 m/s and 2.54–3.23, respectively, with average power density ranging from 318 to 458 W/m^2. The dominant wind directions and the frequency distributions were also determined.

Contents

1. Introduction

Algeria's electricity demand is growing at a rapid, 5–7% annual rate and will, according to SONELGAZ, Company of Electricity and Gas require significant additional capacity possibly 8000 MW by 2010 [1]. In 2007, Algeria's natural gas is the largest source of electricity production as it accounts for almost 98% of total electricity with remaining 1% came from small hydroelectric plants [2]. With this growth in electric demand the Algerian government has realized the importance of renewable energy. It has been realized that the renewable energy projects such as solar, biomass, photovoltaic, geothermal and wind, could be used as tools for the management of reserves and sustainable development of desert communities [3]. In this regard Algeria has huge plan to develop wind energy. Several papers have been written on wind energy in the Algeria's southern territories.

In Algeria work on wind resource assessment dates back to 1990 when the foremost work, in the form of wind atlas was reported by Hammouche [4]. Himri et al. [5] computed Weibull parameters for wind speed distribution at fifteen locations in Algeria. The wind data which covers a period of almost 10 years between 1977 and 1988 was adopted. The average wind speed at a height of 10 m above ground level was found to range from 2.3 to 5.9 m/s. The Weibull distributions parameters (c and k) were found to vary between 3.1 and 7.2 m/s and 1.19–2.15, respectively. It is also found that the windy regions are located at the south west of Algeria, Sahara. The two parameters of a Weibull density distribution function for the three areas namely (Littoral, High-

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lands and Sahara) were compared and wider distributions were observed in the Sahara. It is noticed also that the Weibull distribution give a good fit to experimental data. Himri et al. [6] presented the energy output and economical analysis of 30 MW installed capacity wind farms at three locations using wind turbines of 600, 1000 and 2000 kW. Youcef Ettoumi et al. [7] performed wind power potential assessment for five locations in Algeria using nine types of small and medium wind turbines from five manufacturers. They concluded that most of these turbines are found to produce about 1000–10,000 MWh of electricity per year at 60 m of altitude and can easily satisfy the electricity need in irrigation and its household applications in rustic and arid regions. In another study Himri et al. [8] performed the analysis of wind speed data and available wind energy in Timimoun. The analysis indicates that overall higher monthly mean wind speeds of the order of 5 m/s or more are observed during March–September. Higher wind speeds were observed in the day time between 09:00 and 18:00 h and relatively smaller during rest of the period. The energy production and capacity factor, obtained using two methods viz. wind power curve of 1000 kW and RETScreen software were compared.

The main objective of this study is to quantify the wind power resource in the Tindouf region, Algeria. Hourly wind data, which were observed between the years 2002 and 2006, were gathered in twelve directional sectors; each one extended over 30° according to the direction from which the wind blows. The means values, wind speeds, wind potential, the dominant wind directions and the frequency distributions were calculated using Wind Atlas Analysis and Application Program (WAsP).

2. Climatic wind data for Tindouf

Tindouf is situated on the south-western region of Algeria. The latitude and longitude of the location of data collection are 27°40′N and 08°06′W, respectively. It is at an elevation of 401 m above sea level. With regard to general weather conditions, the temperature varies from a minimum of −5 °C to a maximum of 50 °C while the temperature gradient between day and night is 30 °C. The Tindouf automatic climatological recording station (Thies, Germany) is located about 05 km from the Tindouf airport and 300 km from the Atlantic Ocean as the crow flies.

It can be further characterized by flat desert terrain with a weak surface roughness. There is no obstacle around wind speed measuring station. This site is readily accessible by a road. The wind data for this study was obtained from SONELGAZ R&D Office [9]. The data available is for 5 years on an hourly basis starting from 2002 and ending in 2006. The wind data measurements were made at an elevation of 17 m above the ground level.

3. Results and discussion

The results are presented and discussed mainly in three sections, i.e. in Section 4, the Weibull statistics of wind speed, the Power flux in Section 5 and the Conclusion in Section 6.

4. Weibull statistics of wind speed

The Swedish physicist W. Weibull is among the first founders of Probabilistic Mechanics of Structures and Materials. His probability laws have been also used in many other applications, such as aerospace, electric power, medical, electronics and every industry. In recent years most attention has been focused on this method for wind energy applications, the many publications for different locations of the world have demonstrated that the Weibull two parameters distributions, is the most widely used to fit the wind speed data [5].

However, the Weibull function can be used to describe the wind speed data, it is a special case of the generalized gamma distribution.

The general form of the Weibull distribution, which is a two parameter function, for wind speed is given by:

$$f(v) = \left(\frac{k}{C}\right) \times \left(\frac{v}{C}\right)^{k-1} \times \exp\left[-\left(\frac{v}{C}\right)^{k}\right] \tag{1}$$

where – k: dimensionless shape factor [−] which describes the distribution of the wind (included between 1.2 and 3.5); c: scale factor (m/s) which characterizes the wind speed; v: average wind speed (m/s).

The relationship between the Weibull parameters c and k is given by the following formulas [10]:

$$c = \frac{\bar{v}}{\Gamma(1 + 1/k)} \tag{2}$$

Gamma is the continuous function defined as:

$$\Gamma(x) = \int_0^{\infty} e^{-v} v^{x-1} dv \tag{3}$$

The wind speed data of the Tindouf station were grouped into twelve directional sectors: north-north west (NNW), north (N), north-north east (NNE), east-north east (ENE), east (E), east-south east (ESE), south-south east (SSE), south (S), south-south west (SSW), west-south west (WSW), west (W), and west-north west (WNW). So, each one extended over 30° according to the direction from which the wind blows.

Fig. 1 shows that the yearly values of the two Weibull parameters, the scale parameter c (m/s) and the shape parameter k (dimensionless) are 8.0 m/s and 3.02 in 2006, 8.9 m/s and 2.85 in 2002, respectively. It is obvious that the parameter k has a much smaller spatial variation than the parameter c. it is also noticed that both parameters k and c tend to increase when the wind direction considered becomes more predominant.

5. Power flux

Power flux or wind power density expressed in Watt per meter square (W/m^2), it is considered to be the best indicator to determine the potential wind resource, which is critical to all aspects of wind energy exploitation, from the identification of suitable sites and predictions of the economic viability of wind farm projects through to the design of wind turbines themselves [11].

As seen in Fig. 2 the yearly mean wind power density varies from 318 W/m^2 in 2006 to 458 W/m^2 in 2003,the results indicate that investigated site has good wind energy potential for the utilization. The wind availability analysis is carried out in terms of the occurrence of number of hours during which wind remained in

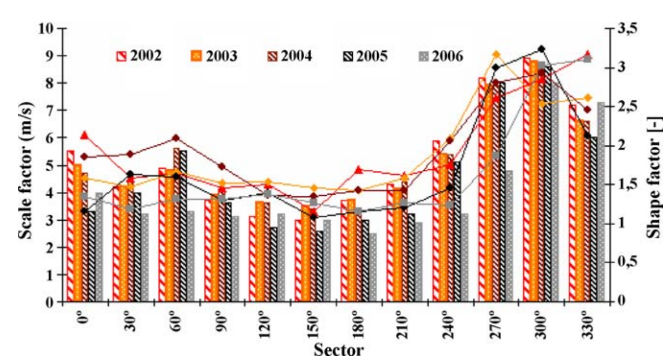


Fig. 1. Shape and scale factors in Tindouf station.

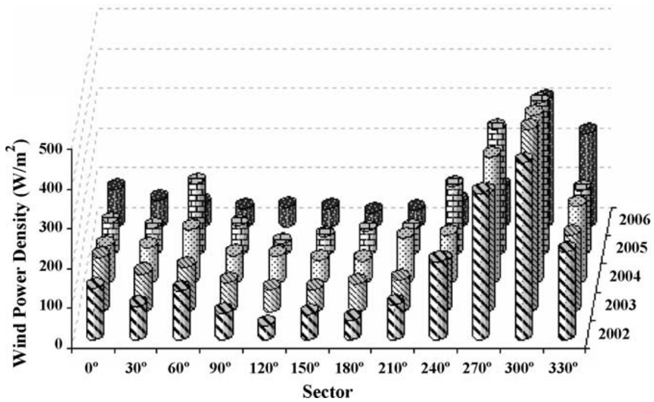


Fig. 2. Annual mean flux density at Tindouf station.

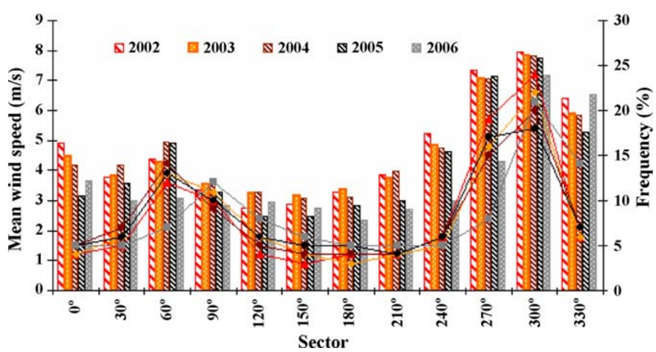


Fig. 3. Velocity distributions at Tindouf station.

a certain wind speed interval in a particular wind direction. The sectoral frequencies of wind direction at the given meteorological station are depicted in Fig. 3. According to this figure, the dominant prevailing wind direction for the period extending from 2002 to 2006 is 300°. In this region, western winds are effective.

After west-south-western winds are most effective. It is also observed that the annual mean values of the wind speed are 7.95 m/s for 24% of the time in 2002 and 7.19 m/s for 21% of the time in 2006, respectively.

6. Conclusion

The following conclusions can be drawn from the results of the present study:

- Using wind data, consisting of hourly wind speed records over a 5-year period, 2002–2006, wind characteristics at Tindouf, Algeria were investigated.
- The average wind speeds for the site studied were found to range between 7.19 and 7.95 m/s.
- The yearly values of k and c at this site were found to vary between 2.85 and 3.23, and 8.0–8.9 m/s, respectively.
- Both Weibull parameters show an increasing trend as the direction considered moves to the more dominant direction.
- Western winds are the more dominant direction.
- The mean power density were found to range from 318 to 458 W/m^2.
- At the end the present work is only a preliminary study in order to assess wind energy analysis of Tindouf, Algeria and give useful insights to engineers and experts dealing with wind energy.

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